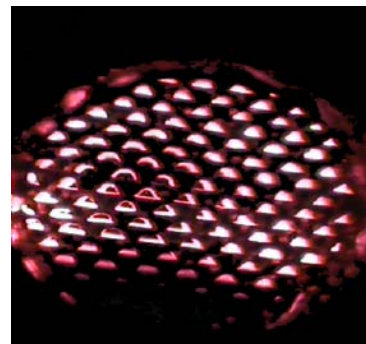


Expanded Capacity Microwave-Cleaned Diesel Particulate Filter

Diesel Engine Emissions Reduction Conference
August 29, 2002

Dick Nixdorf
Industrial Ceramic Solutions, LLC
Oak Ridge, Tennessee
(865) 482-7552

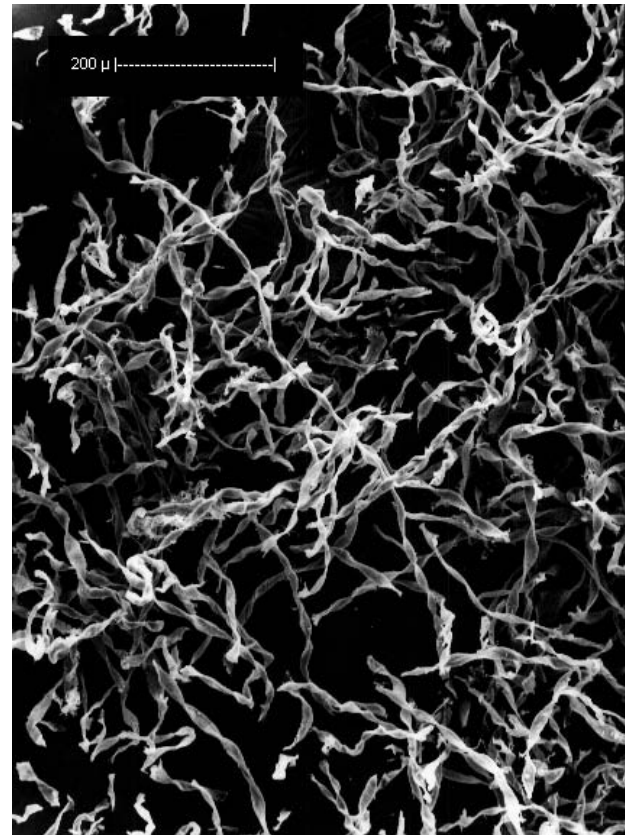


Content of the Presentation

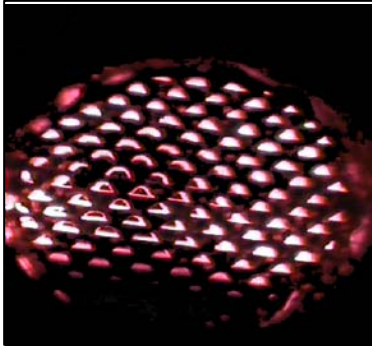
1. Technology description and status
2. Stationary diesel engine and vehicle particulate emissions test data
3. New pleated filter concept and prototype
4. Work planned for 2003

ICS Microwave-Sensitive Silicon Carbide Fibers The Core of the Technology

- **Efficiently Converts Microwaves to Thermal Energy**
- **Large, Non-Respirable SiC Ceramic Fiber Material**
- **Existing High Production Capacity**
- **Patent Filed by ICS**



Microwave Filter System Stage of Product Development



**Commercial Applications
Require Uniform Heating
- a Competitive Advantage**



**Volume Processing
ThermaPore™ Media**



**On-Road Vehicle Testing
On Several Engine Types**



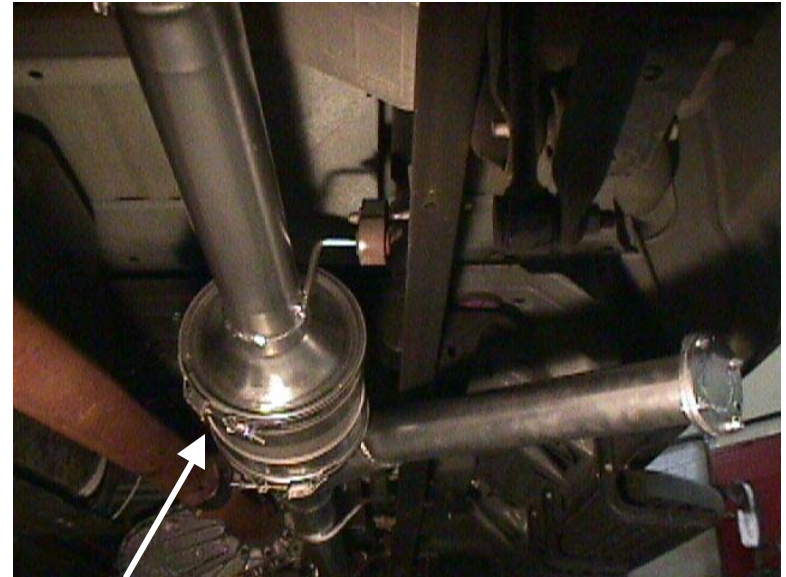
**Platform Technology
Multiple Applications**

Durability Testing of Ceramic Filter on the 7.3-Liter Ford F-250 Truck



2.8-Liter Cartridge

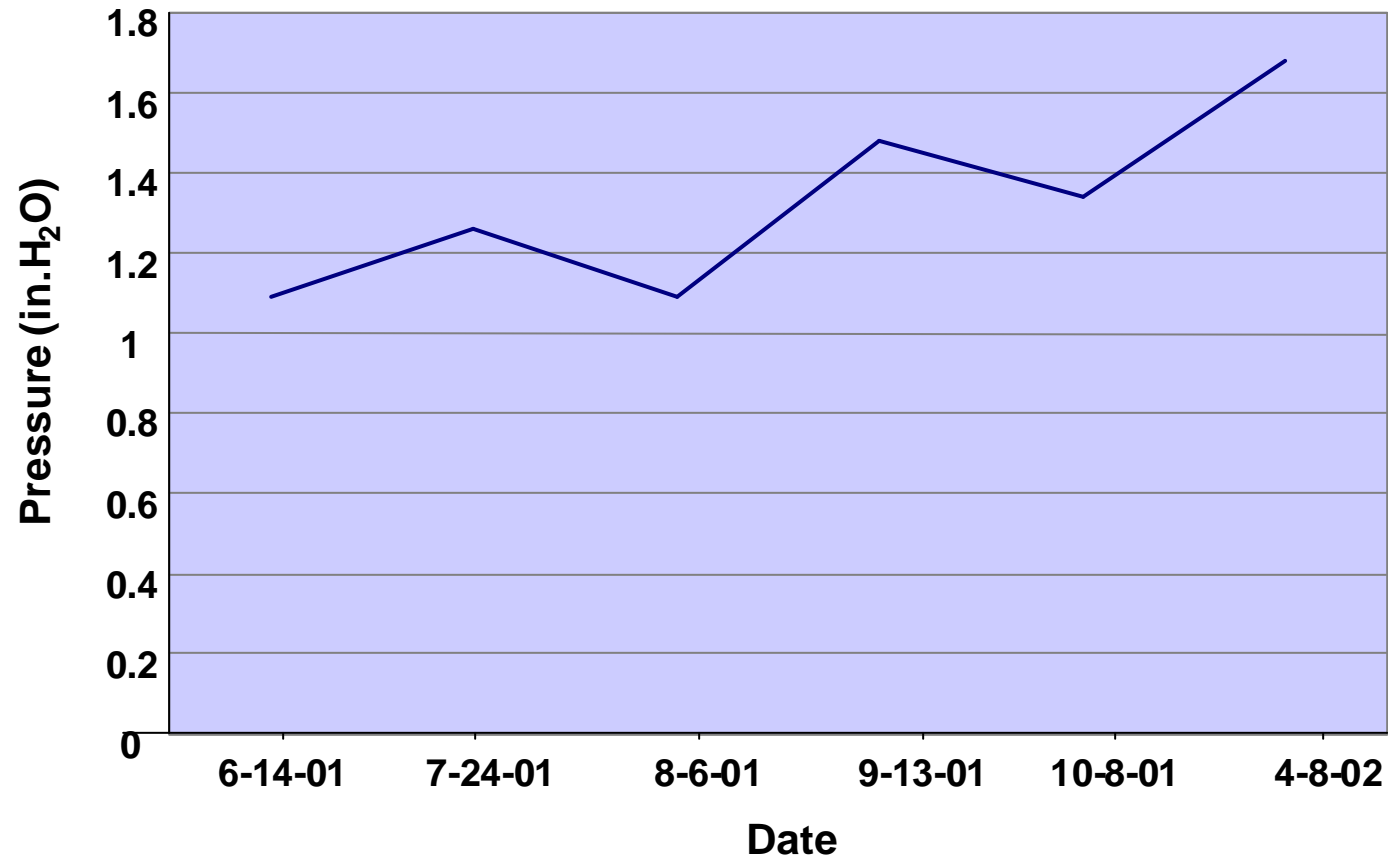
- Exhaust noise quieter than muffler



- Cartridge removable from can by Engine Control Systems
- Records continuous pressure and temperature at filter

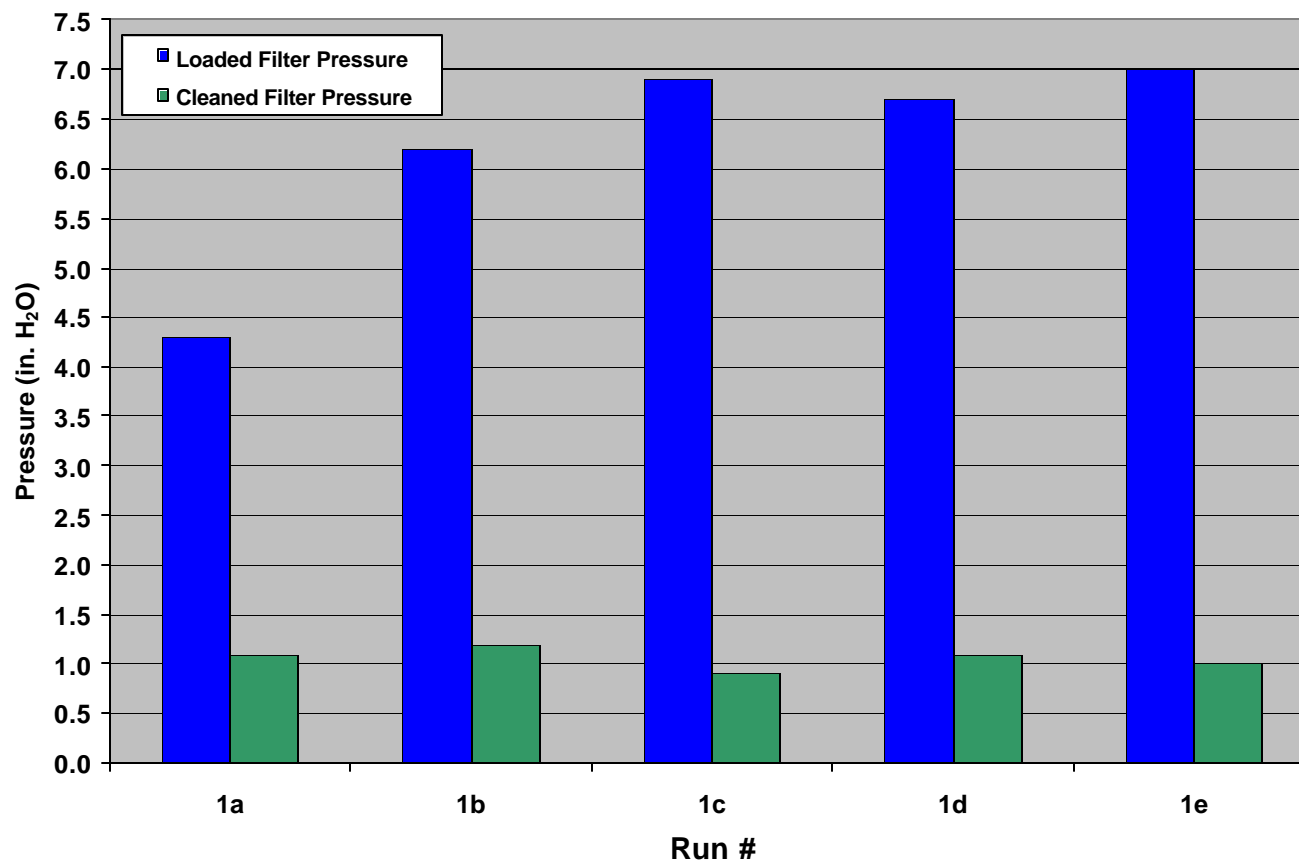
Durability Testing of a Ceramic Filter on the 7.3-Liter Ford F-250 Truck

Cleaned Filter Backpressure at Engine Idle



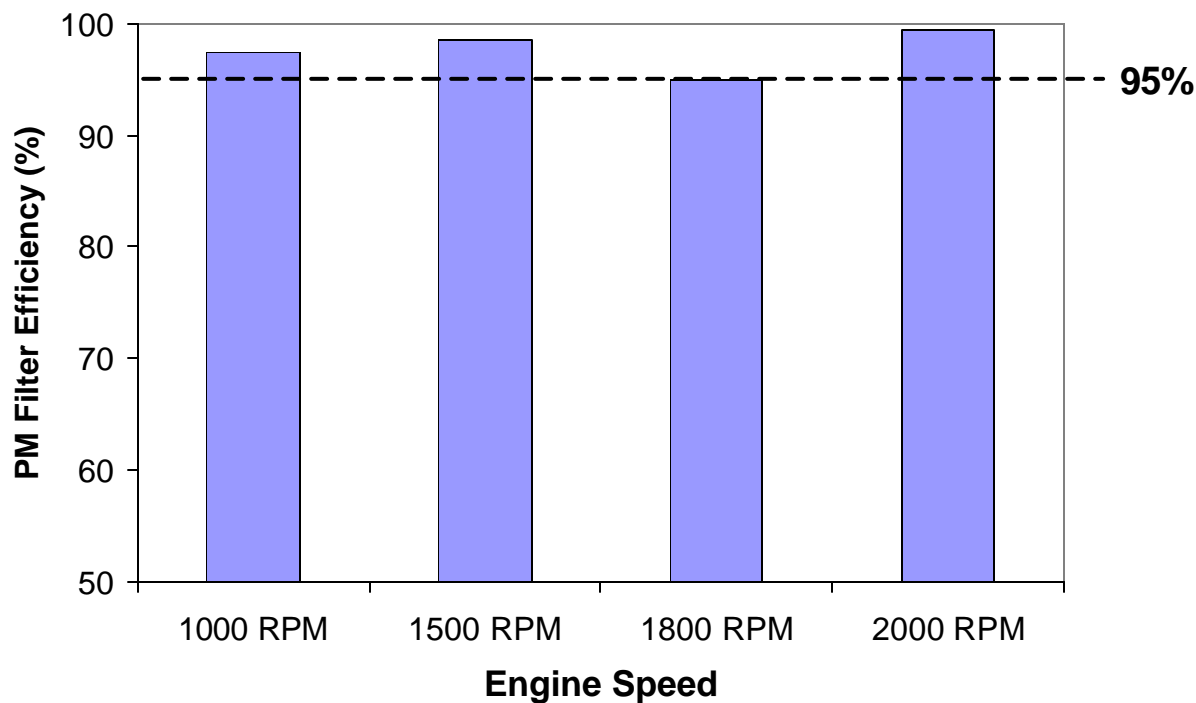
Consecutive Idle Condition Jetta Vehicle Microwave Regenerations

Between 60-Mile Driving Cycles



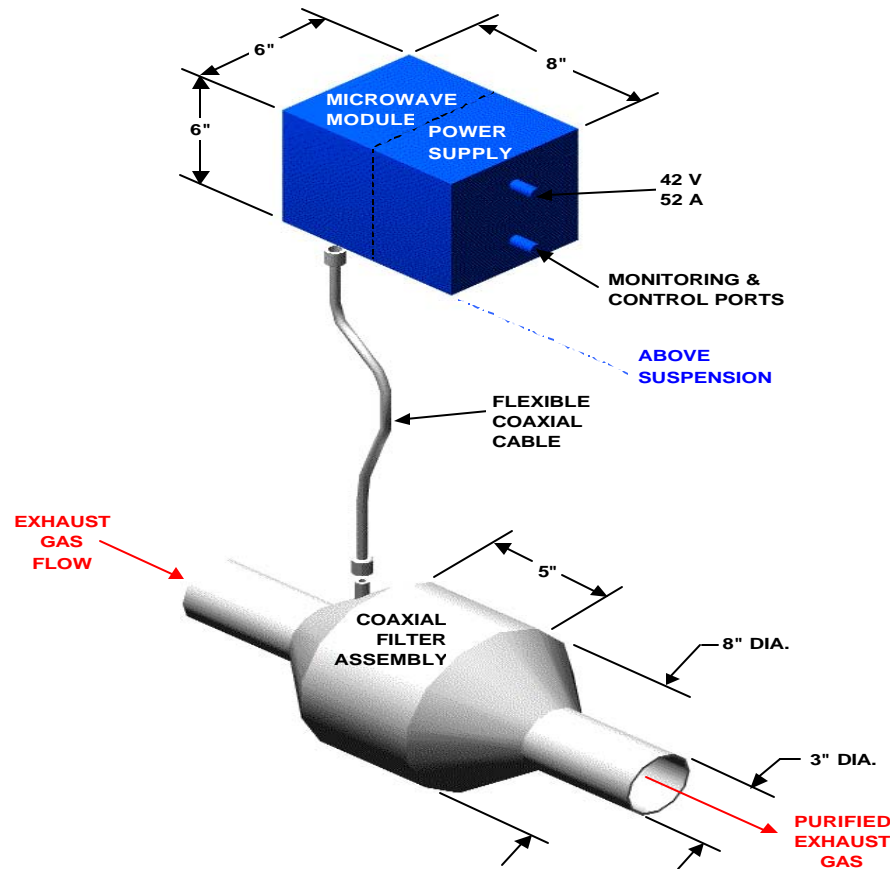
1.9-L Volkswagen TDI Stationary Engine Data TEOM Measurements by ORNL

***PM filter efficiency > 95% for
steady-state points***



Northrop Gruman Electron Devices Concept

ICS/Litton Microwave Particulate Filter



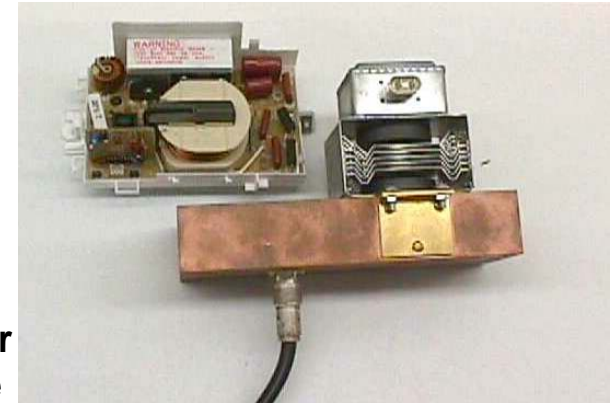
Materials and Design Improvements in FY 2002

N-G/ICS 2-Zone Microwave Igniter

(Patent Filed)



**5" x 5" Filter and
Can Components**



**1.3 kw Magnetron and Power
Supply in 8" x 8" x 6" Space**

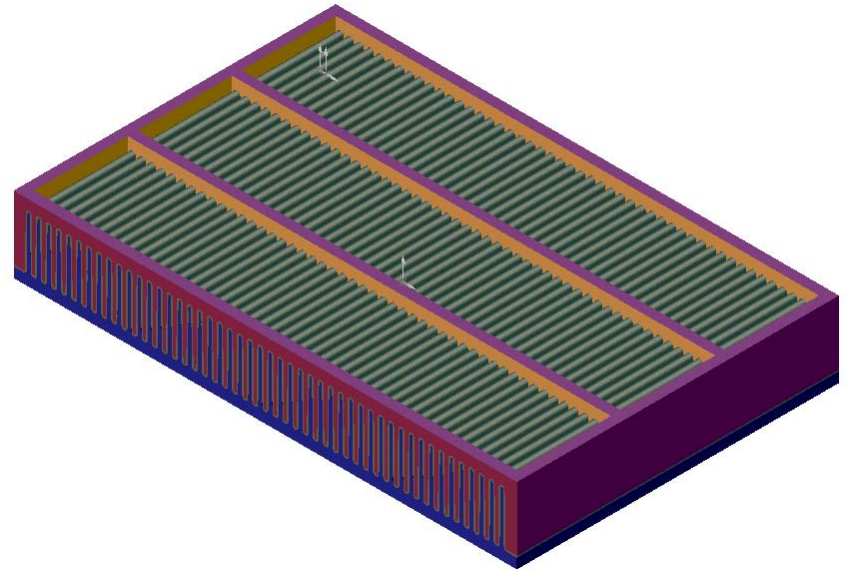
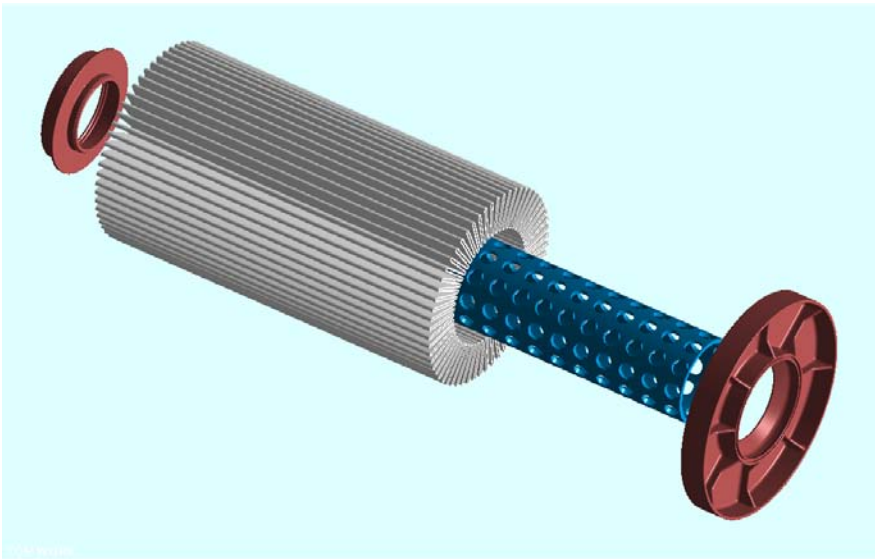


**Filter Can with
Coaxial Antenna**



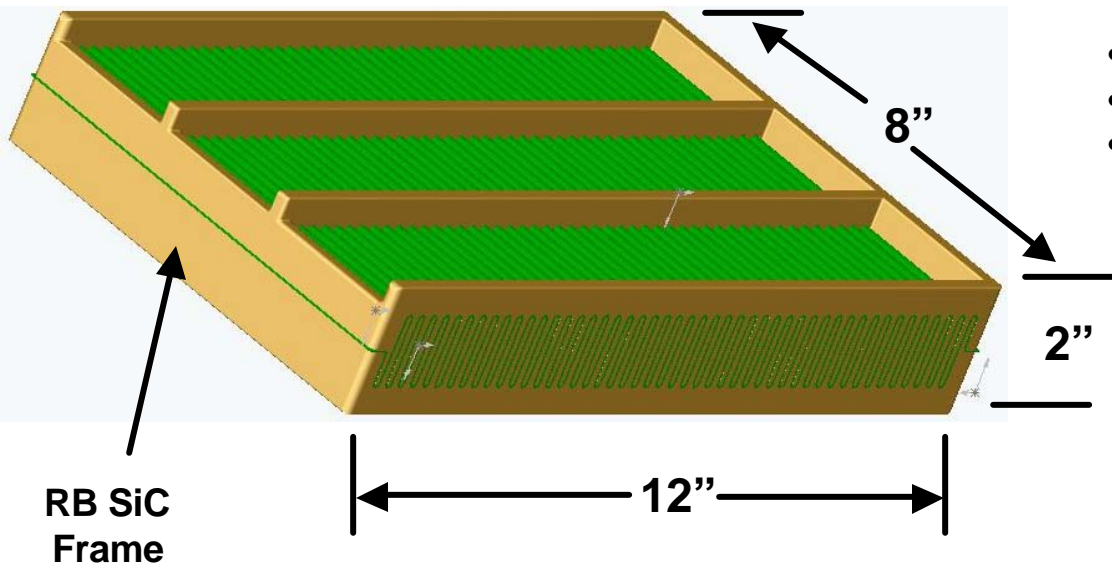
**Microwave,
Coaxial Connector
& ICS Exhaust Filter**

Pleated Filter Cartridge Design Allows Filtration of Large Exhaust Flows



- Reduces backpressure
- High soot and ash loading capacity
- Low thermal mass
- Low production cost

New ICS Pleated Filter Cassette

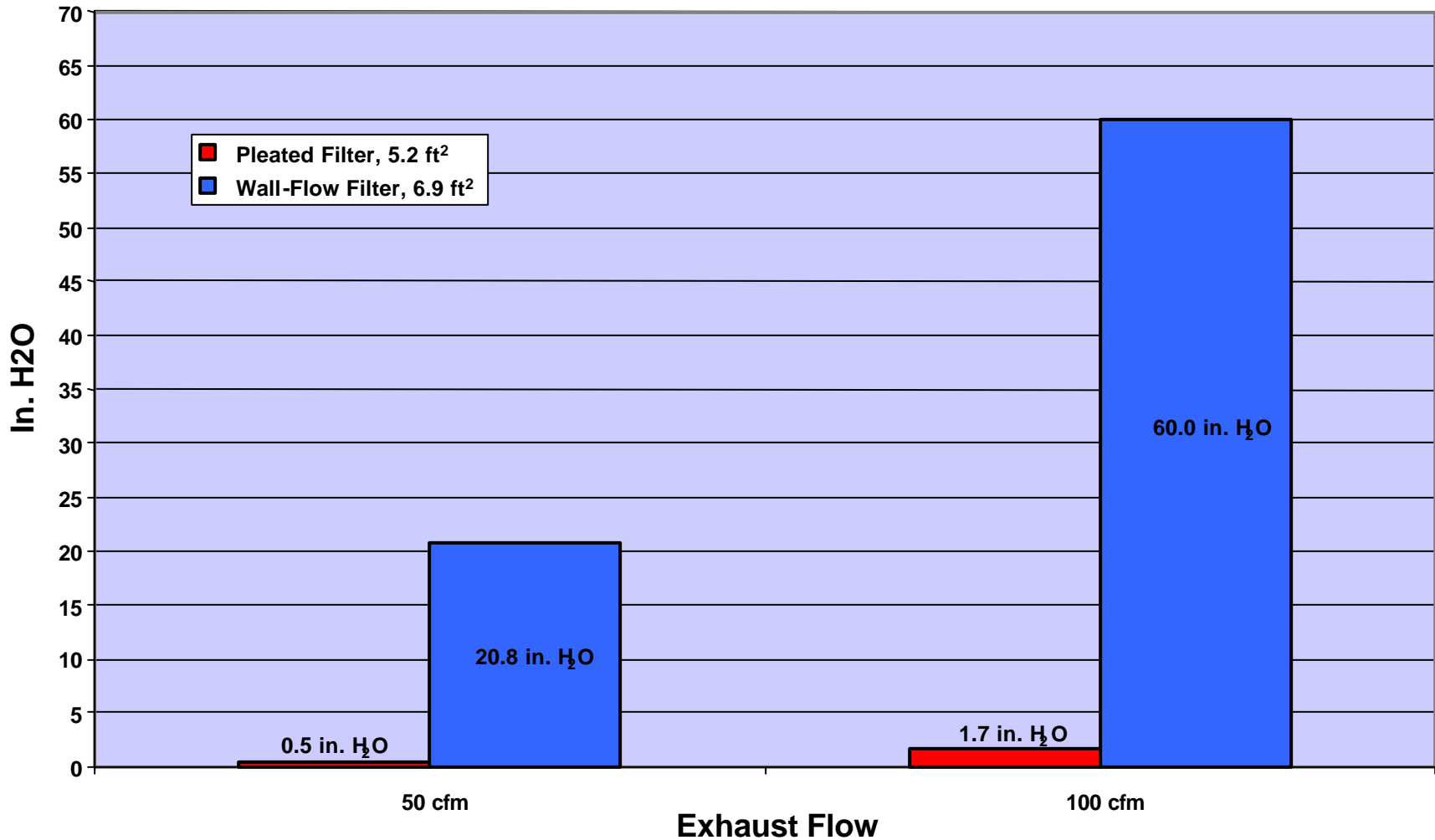


- 25 to 50 micron pore size
- Backpressure = $1/20^{\text{th}}$ Wall-Flow
- High soot conditions preferred

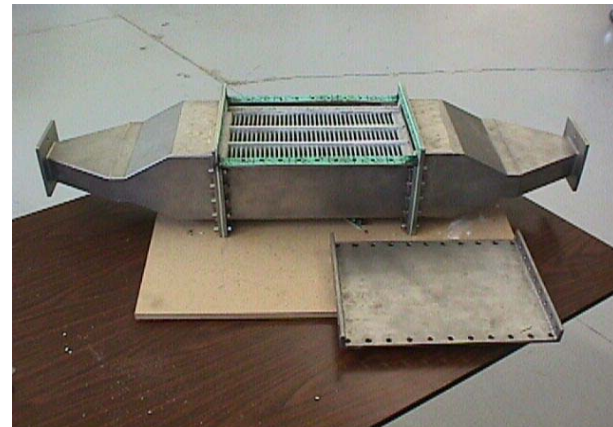
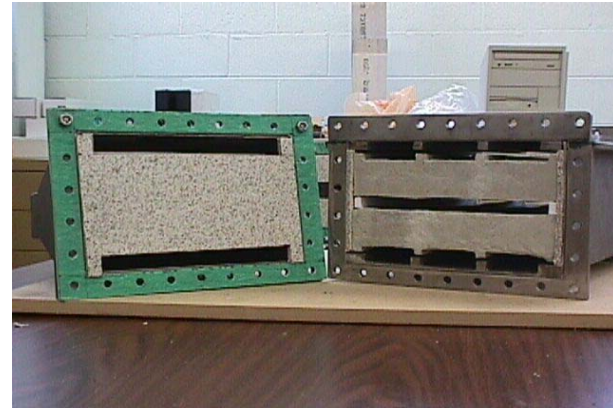


Patent Pending

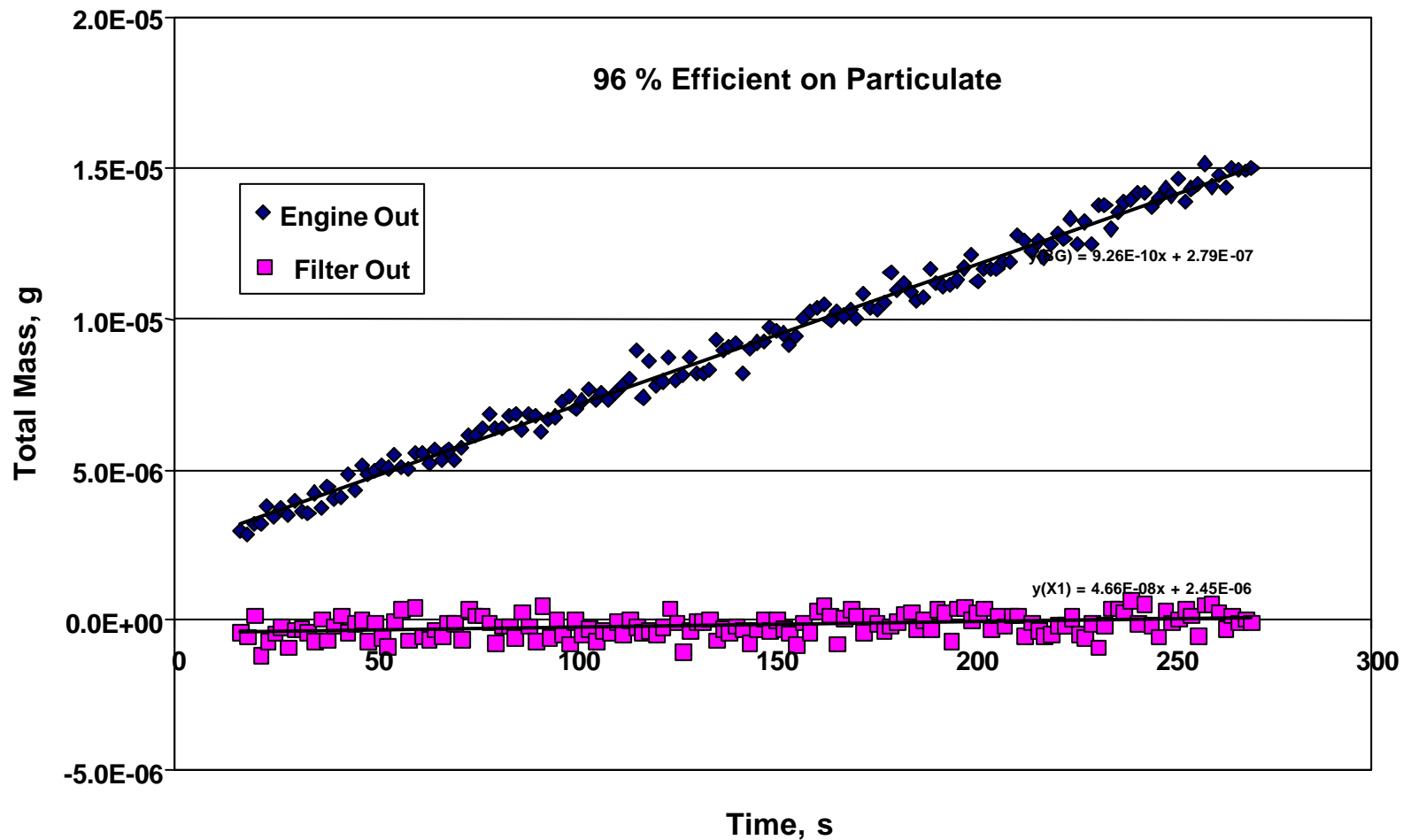
ICS Pleated Fiber Filter vs. Wall-Flow Fiber Filter Backpressure Comparison



ICS Diesel Pleated Cassette Filter Testing at ORNL Mercedes 1.7-L Test Engine

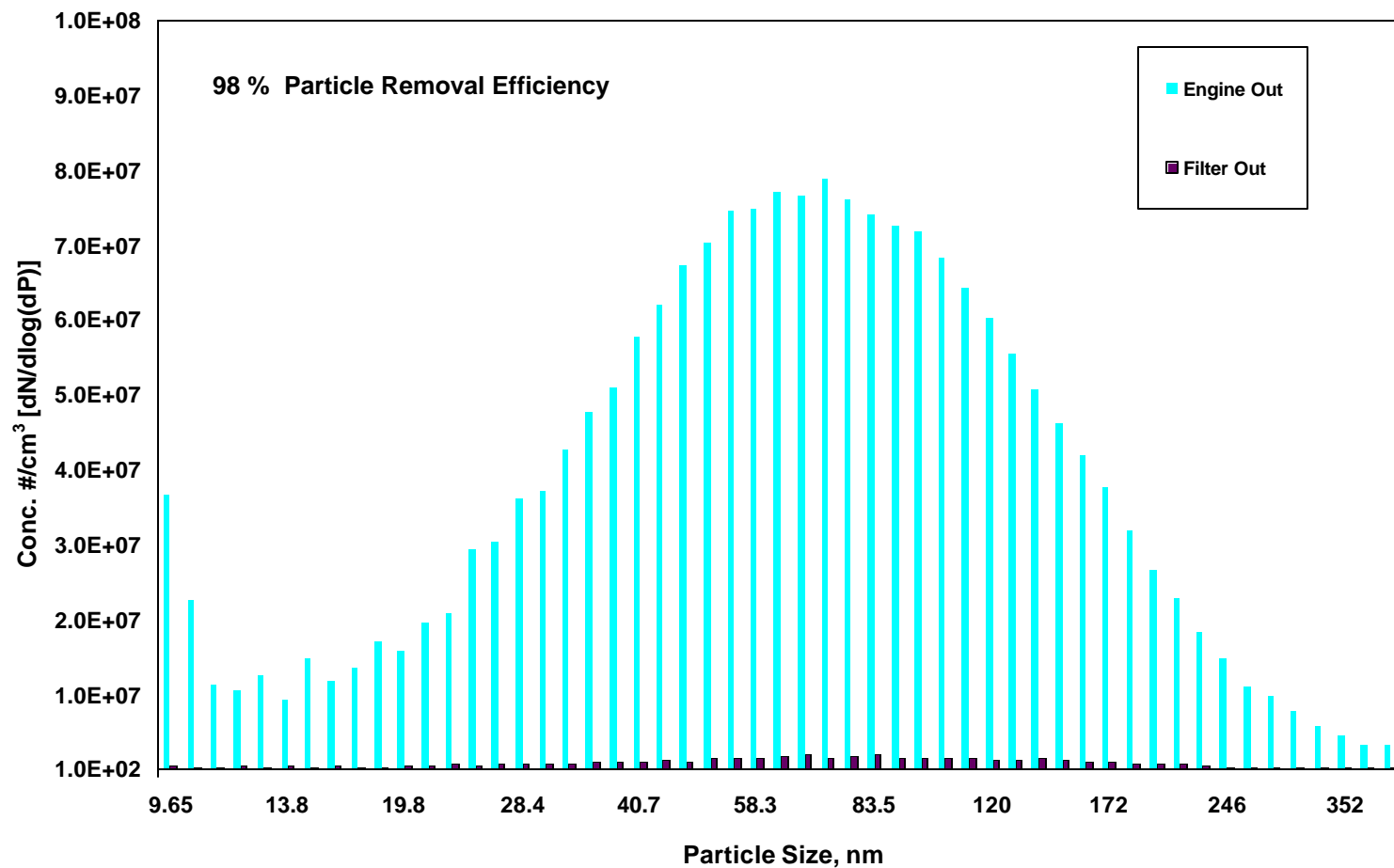


Pleated Filter TEOM Carbon Mass Data 1.7-Liter Mercedes at ORNL



Pleated Filter Particle Size Removal Data

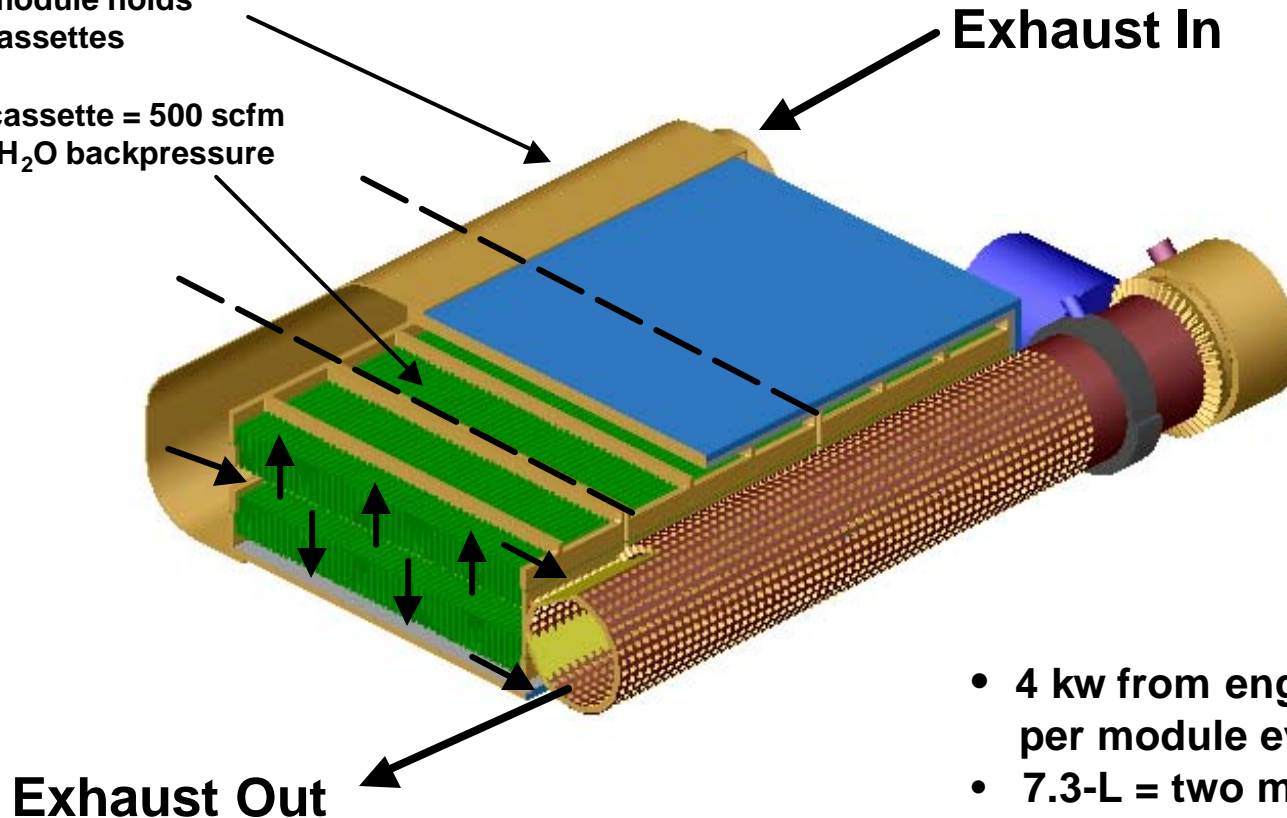
1.7-Liter Mercedes by ORNL



New ICS Pleated Filter Mw-DPF for Diesel Engines Less Than 3,000 cfm Exhaust

One module holds
two cassettes

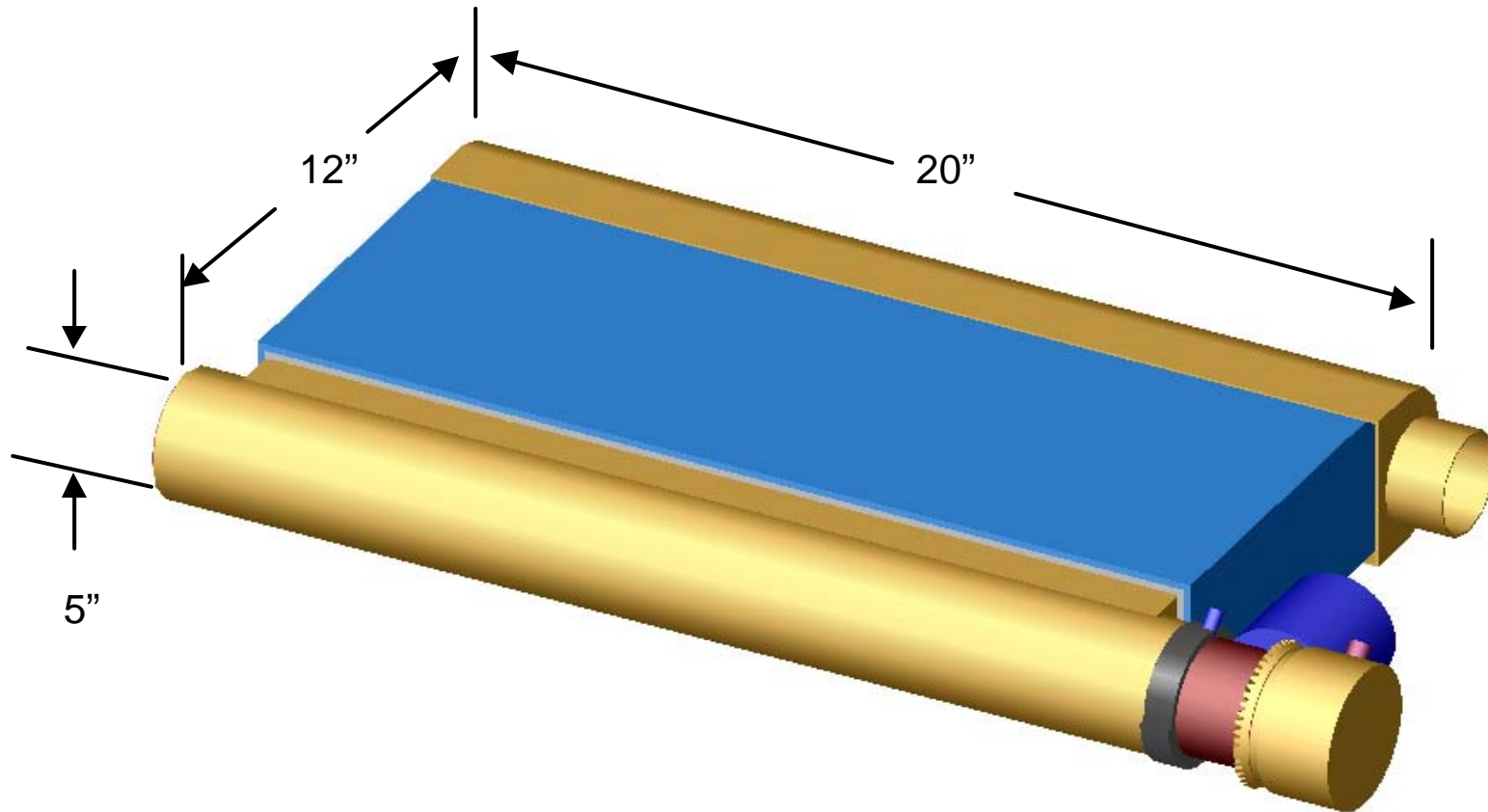
One cassette = 500 scfm
@ 8" H₂O backpressure



- 4 kw from engine at five minutes per module every three hours
- 7.3-L = two modules
- 14-L = five modules

Patent Pending

***Pleated Filter Assembly for 1,000 - 2,000 cfm
7.3-L, Two Module Same Size as a Muffler***



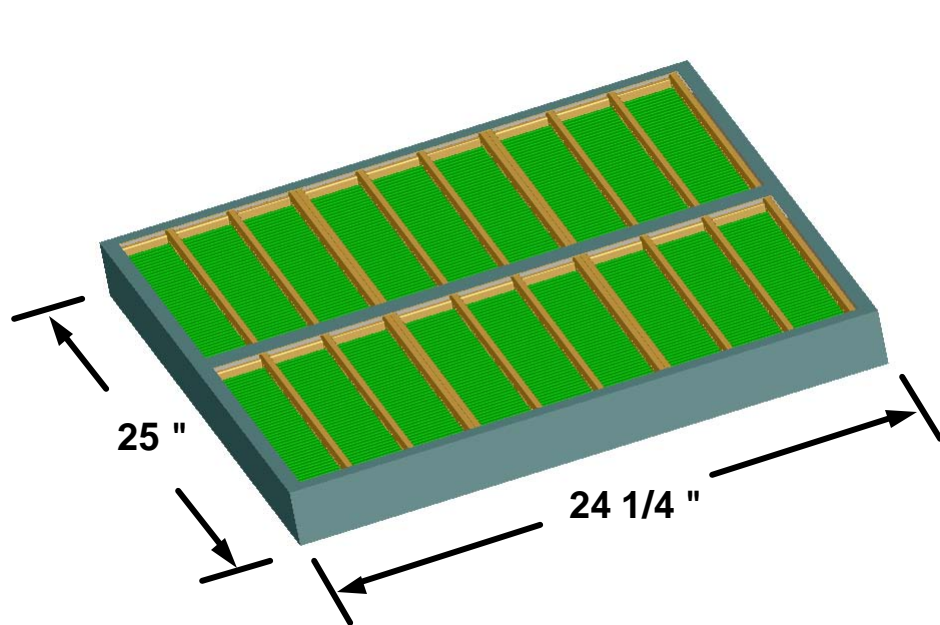
Current Path to Diesel Vehicle Market

Ford F-250 7.3-Liter Diesel Truck 7,000-mi Track Test

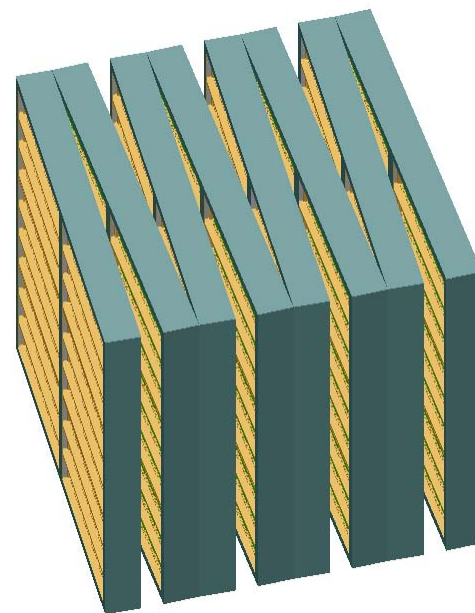
1	Manufacturer pleated filter cartridges	Aug/02
2	Fabricate four cartridge filter system	Aug/02
3	Install stock generator and microwave	Sept/02
4	Pleated filters to Cleaire for retrofit tests	
5	Road test 7.3-L filter system	Sept/02
6	Conduct 7,000 mile track test	Oct/02
7	Move to Detroit for testing at auto companies	Dec/02
8	Move to Donaldson for demo	Jan/03
9	Select partners for commercial product production	Feb/03

U.S. DOE Office of Energy Efficiency	- Project funding
Lydall Technical Papers	- Ceramic fiber media
Goodrich Aerospace & ORNL	- Filter durability improvements
Donaldson	- Exhaust valves

Six Cassette Filter Panel for Diesel Exhausts Greater than 3,000 cfm



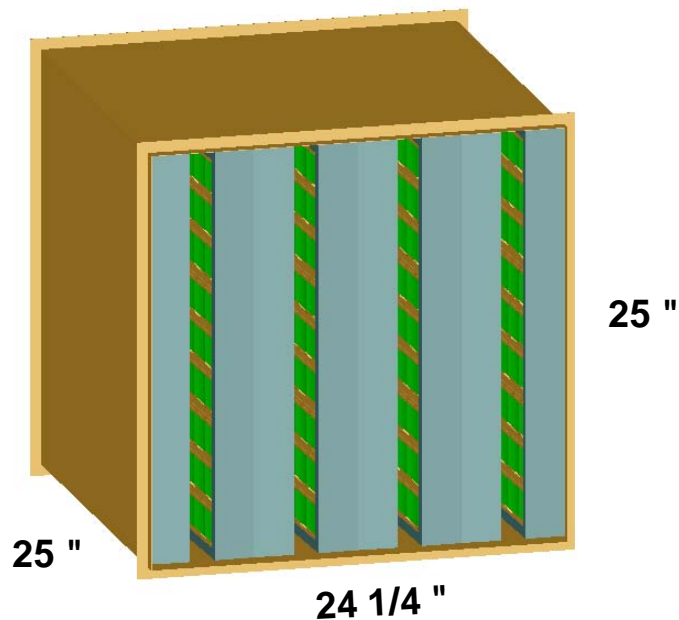
Six-Cassette Panel
[36 ft²]



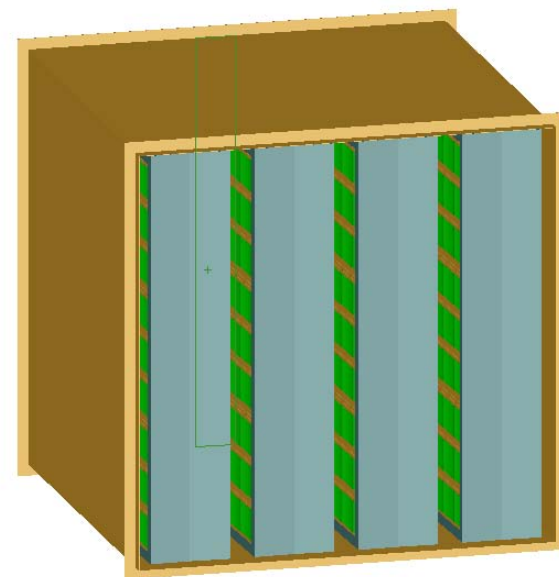
Eight- Panel Filter
[288 ft²]

ICS Pleated Filter Canned Assembly Handles 3,000 cfm @ ½" H₂O

13,000 cfm 2,600 HP Caterpillar Generator would require four modules
(passive catalyst or Microwave clean off-line)



Front View



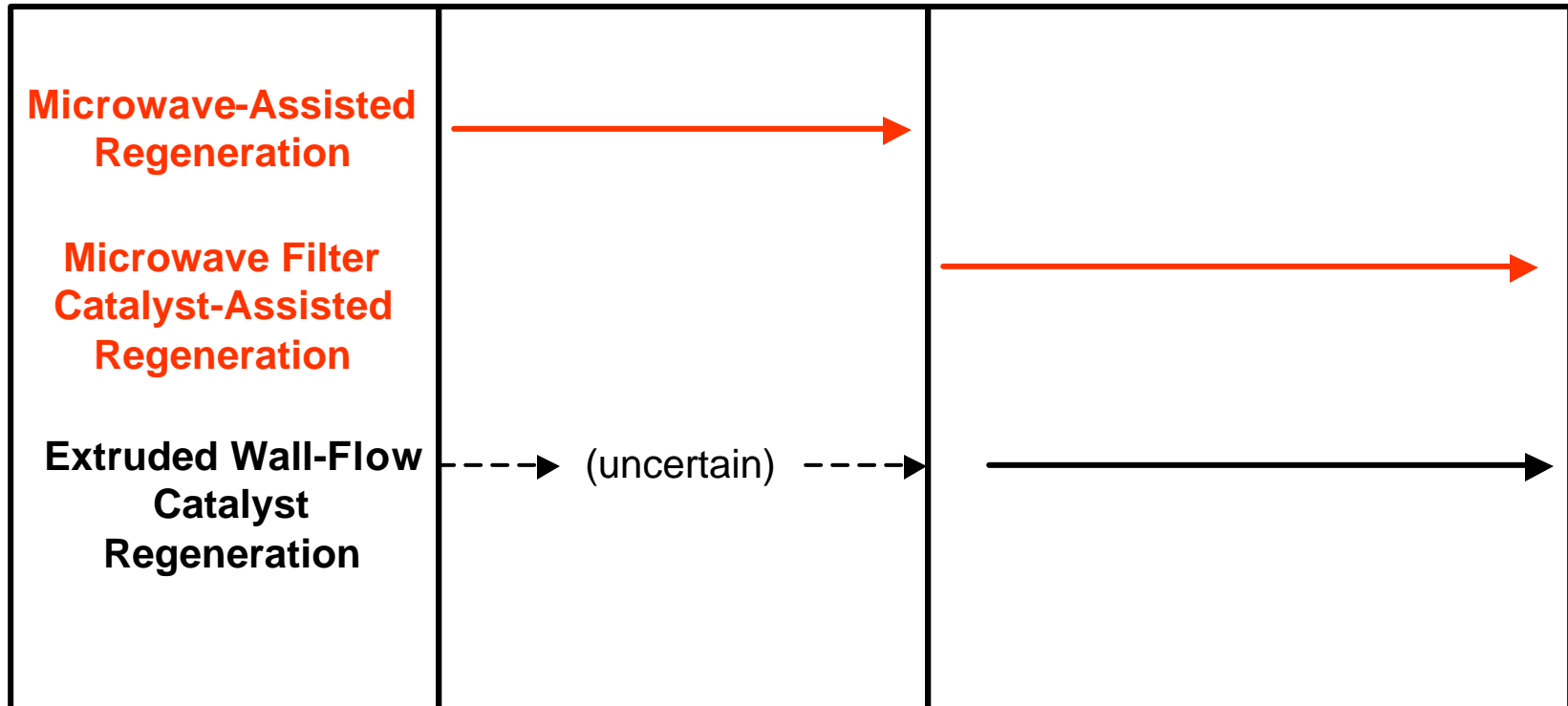
Rear View

Regeneration Options for the ICS Microwave-Cleaned Particulate Filter System

Cold-Start to Idle
0 – 100°C

Urban Driving
100-300°C

Full-Load Operation
300-500°C



Unique Attributes of the Microwave-Regenerated Diesel Particulate Filter

- **Regenerates at exhaust temperatures below 300°C at all engine operating conditions**
- **Clean filter backpressure is 20 times less than wall-flow DPF**
- **Negligible fuel penalty**
- **Regeneration does not require fuel or engine management**
- **Oxidation catalysts can be applied for more systems options**

Future Work on Mw-CDPF

- **7,000-mile track test with FTP emissions testing (4th Qtr 2002)**
- **Demonstrate test truck at various diesel companies (1st Qtr 2003)**
- **Set up duplicate system on 200 kw diesel generator for continuous operation (1st Qtr 2003)**
- **Pleated cartridge production (2nd Qtr 2003)**
- **Run test truck through 25,000 mile road testing with periodic FTP emissions (2003)**
- **Work with catalyst suppliers to develop efficient technology (2003)**
- **Work with microwave suppliers to optimize microwave source**
- **Investigate application of NO_x catalyst for microwave desulfuring**